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GYPSUM AND OTHER SULFUR MATERIALS

FOR SOIL CONDITIONING

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oes Your Soil Need These Materials?
If So, Which Should You Use?
And How Much?

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GYPSUM AND OTHER

LARGE QUANTITIES OF SULFUR . . .

. . . and its compounds—especially gypsum—have been bought in recent years to apply on soils or in irrigation waters. Such applications have improved the physical condition of many soils. On other soils they have been of doubtful value.

TO HELP YOU DECIDE . . .

. . . whether sulfur materials would be worth trying with your own soil, this circular tells when you can expect an application ***to improve the physical condition*** of the soil and when you cannot.

However, it will not help you if you are interested in using these materials for other purposes. It does not deal with their use to acidify soils to a definite point for disease control or in the hope of developing a better nutrient supply. Nor does it discuss the use of sulfur as an essential plant nutrient on those few soils where it is needed.

SUPPOSE YOU DO DECIDE . . .

. . . that some sulfur material might improve your soil. Then the circular will help you decide which to buy (page 7). It gives pointers on calculating the amount you need (page 8). It tells what the various sulfur materials are, how they work, and how to apply them (pages 9–12).

This circular does ***not*** deal with other phases of alkali reclamation—it does not tell you how to level, drain, irrigate, and crop.

SULFUR MATERIALS FOR SOIL CONDITIONING

WILL THESE MATERIALS IMPROVE THE PHYSICAL CONDITION OF YOUR SOIL?

1 ***If your soil is permeable,*** if water penetrates it readily, ***the answer is NO***—at least not enough to be worth while. This holds even for permeable alkali soils, if they remain permeable when leached with water.

2 ***If your soil is a nonalkali heavy soil, or if it has become impermeable because of packing or plow-sole, the answer is probably NO***—but possibly ***YES.*** Applying organic matter may help more; see page 4.

3 ***But if your soil is impermeable because of black alkali, the answer is YES***—that is, if you can provide adequate leveling, drainage, and water for leaching.

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How permeable is your soil?

On California soils, sulfur materials are used principally to improve soil physical condition.

As soil conditioners, sulfur and gypsum and other sulfur compounds have been used successfully for many years. In some instances, however, the applications of sulfur materials for this purpose are of questionable value. What are the conditions of soil that you can expect to improve by adding sulfur materials?

The first point to consider is whether or not your soil is permeable.

The rate at which water penetrates the soil varies with texture. Water will not penetrate a clay or adobe soil as fast as a loam or sand. If your soil is heavy (fine-textured), *fairly* slow penetration does not mean that it is impermeable. But your soil *is* impermeable if water stands on it a long time and yet the soil is dry a foot or less below the surface.

Water penetration is important in deciding about the value of sulfur applications because if water penetrates your soil readily, applying sulfur materials to improve the physical condition of the soil is of little value.

Field experience indicates that this is true, in spite of the popular belief that these materials improve tilth, aid plowing—improve soil structure generally.

Permeable alkali soils can be reclaimed without sulfur materials

Soils that are popularly called "alkali" are those that contain harmful amounts of soluble salts (white alkali, or saline soils) or adsorbed sodium (black alkali) or both.

If you have an alkali soil that is permeable—and remains permeable when large amounts of water are applied—it is a saline soil, and does not need sulfur materials. You can reclaim it by flood-irrigating with ample water—provided you have good drainage, level your land well, and grow a crop. Sulfur materials will not take the place of leaching.

If you have an alkali soil that is at first permeable but becomes impermeable when you leach it, see page 5.

Gypsum is of questionable value in making nonalkali heavy soils easier to work

Gypsum is widely used on fine-textured, or heavy, soils in an effort to make them more permeable or easier to work. Laboratory tests have, indeed, indicated that it might be useful on such soils. But field tests have not shown consistent benefits. Before you make applications on a large scale, it would be wise to try a sample plot to see if there is any noticeable improvement in water penetration, tilth, or crop production. Do not overlook the possibility that the same amount of money put into barnyard manure, cover-crops, or some other good source of organic matter might improve the physical condition at least as much as gypsum would—and at the same time add nutrients.

Soils impermeable because of packing or plow sole . . .

. . . may or may not be improved by sulfur materials. So far we have been discussing soils where water penetration is not a problem. But what about impermeable soils?

If water does not penetrate your soil readily, the next thing is to find out *why*. If the soil has been cultivated while it was wet, it may be *packed*. Heavy vehicles—trucks, tractors, spray rigs—driven over it may also pack it. If it has been cultivated to the same depth for several years, a *plow sole* may have been formed. Packing or plow sole may make the soil impermeable. If you are not sure whether your soil is impermeable because it is packed or has plow sole, your farm advisor may be able to help you.

If the soil is impermeable because of such conditions, sulfur materials may or may not improve it. A small test plot should enable you to find out whether applications of these materials will be worth while on your soil. Other remedies, such as covercropping and reduced cultivation, may be more effective.

Black alkali soils can be improved by sulfur materials

If your soil is impermeable, and yet is not packed and has no plow sole, the trouble may be black alkali. If so, *then sulfur materials, properly chosen and applied, will help you to reclaim it.*

What is a black alkali soil?

A black alkali soil is one in which too much sodium is *adsorbed on the clay.*

Fine clay particles hold bases such as potassium, sodium, calcium, and magnesium chemically attached to their surfaces. These bases are then said to be adsorbed. (Because the various bases can replace each other on the clay particles, they are also called replaceable, or exchangeable.)

If too high a percentage of the total adsorbed bases is sodium, the soil has certain characteristics that make it unfavorable for the growth of plants. Excess adsorbed sodium causes high soil alkalinity, stickiness, and impermeability to air and water.

Too much adsorbed sodium also produces sodium carbonate in many soils. This compound in the soil water dissolves some of the soil organic matter and forms a black solution. When the solution evaporates, it leaves a black deposit. Farmers in the West long ago gave this condition the name "black alkali." But there may be too much adsorbed sodium without a black deposit.

What percentage of adsorbed sodium is "too much"? This differs in different soils. With some soils there may be trouble if the adsorbed sodium is even as little as 10 per cent. The average percentage that causes trouble is about 15 per cent. (Percentages here are not on the basis of weight or volume but on the basis of chemical equivalents.)

The sodium clay may exist naturally. Or it may have been formed by irrigation or seepage water containing sodium, or by continuous use of fertilizers containing sodium.

Some white alkali soils become impermeable when they are leached

Many white alkali (saline) soils, such as those in the Imperial Valley, can be reclaimed by leaching alone, as we noted on page 4.

But other soils that are permeable at first also contain black alkali, which is masked by the white alkali. These soils take on the characteristics of black-alkali soils when the white alkali is removed by leaching. At this stage sulfur materials will benefit them in the same way as soils that are black alkali to begin with.

Some white alkali soils become less permeable when leached, even though sodium is not a problem. The effect seems to be due just to the lowering of the salt content. Sometimes gypsum applications will benefit these soils.

The best procedure with a white alkali soil is to try leaching alone first. Then if you find that the soil becomes impermeable, apply sulfur materials.

How can you tell whether you have an impermeable alkali soil?

First find out—if you do not already know—whether your soil is permeable. Flood-irrigate it, and see whether the water penetrates as fast as you could expect for its texture. (Remember that if your soil is fine-textured rather slow penetration does not mean your soil is impermeable.)

- If your soil is impermeable and there is a black deposit on it. it is probably a black-alkali soil.

- If your soil is impermeable but there is no black deposit, ask yourself whether past practices could have resulted in packing or plow sole. If you are quite sure that this is not the explanation, then your soil may be black alkali, even though there is no black deposit.

- Your farm advisor may be able to help you. He may be familiar with similar soil on near-by farms. Or he can tell you how to go about getting an analysis if you need one.

- If you live in a county that does not have a farm advisor, you can write to the Agricultural Extension Service, University of California, Berkeley 4, California.

Will it pay to apply sulfur materials to a black alkali soil?

You can scarcely farm a black-alkali soil without reclaiming it. If your soil is low enough in salts so that you can grow an alkali-tolerant crop on it, this may be the most practical way to reclaim it. A good way is to grow an irrigated pasture in which you have planted such crops as bur clover, white sweet clover, bird's foot trefoil, alfalfa, Rhodes grass, Sudan grass, or Bermuda grass. A winter crop of barley might do the job.

But on many black-alkali soils the most practical way is to apply sulfur materials.

Whether or not it will *pay* you to apply sulfur materials depends on the cost of the treatment and the value of the crop you plan to raise. Also you must be able to provide the proper conditions; just applying sulfur materials will not reclaim your soil. They merely condition your soil and enable you to leach out the excess salts. which will permit you to start a cropping program.

Your land must be well leveled so that you can flood-irrigate evenly on all parts of the field. Irrigating is needed first to promote the action of the sulfur materials and then to wash out the excess salts.

Your land must be well drained, so that you can leach the salts below the root zone of your crop.

You will need plenty of water for the leaching.

You will need to grow (at first) a crop that is tolerant of alkali.

The details of land preparation, irrigating, after-treatment, cropping, and other phases of alkali reclamation are beyond the scope of this circular. We are concerned here only with the question of whether your land needs sulfur materials.

Gypsum improves certain irrigation waters

One way in which impermeable soils are formed is through the presence of sodium salts in the water used for irrigating (page 5).

Gypsum is sometimes used in certain irrigation waters to prevent this and to improve their rate of penetration. Studies on this problem have been conducted by the University of California, and encouraging results have been achieved in certain areas. Until the results are ready for publication, local experience is your best guide.

Your farm advisor will know whether any tests have been conducted in your vicinity with water and soil conditions similar to yours.

Suppose you have decided that your soil might be improved by applying sulfur materials . . .

WHICH SULFUR MATERIAL SHOULD YOU CHOOSE?

decide on the basis of:

NEED: which sulfur material will serve your purpose?

If your soil contains lime (calcium carbonate), use ***any*** of the sulfur materials. Most soils do contain enough lime. To find out whether yours does, use the simple test given on page 11.

If your soil lacks lime, use ***gypsum;*** or you can use other sulfur materials if you also apply lime (see page 11).

If you have high-sodium irrigation water: use high-grade, finely ground ***gypsum.***

COST: what is the best buy?

Compare materials on the basis of price per pound of sulfur in them. The price of actual sulfur in a compound depends upon (1) the percentage of sulfur in the ***chemically pure*** compound (for example, the percentage of sulfur in pure calcium sulfate) and (2) the degree of purity in a ***given grade or brand*** (for example, the percentage of calcium sulfate in a given grade of gypsum).

To find out how much sulfur there is in the chemically pure materials you are considering, see the paragraphs on those materials on pages 10 to 12.

To find out how pure the grade is that you are thinking of buying—what its percentage of purity is—look at the identification tag or label on the package.

Then multiply these two percentages together to get the percentage of sulfur in a particular grade or brand.

The California Agricultural Code classifies the sulfur materials used in soil conditioning as agricultural minerals.

It stipulates that an analysis of the material must be furnished by the seller and stated on the identification tag. ***Watch for this analysis;*** it is your guide as to how much the material is worth.

If you have to add lime to certain materials, remember to include its cost and the cost of applying it in your total costs for them.

Fineness should be considered with materials that are ground. Soluble ones will dissolve faster if they are fine. Any finely ground material can be more evenly distributed among the soil particles where it must do its work. Except for sulfur, a fine-ground material is worth somewhat more than the same grade ground coarse. Coarse-ground sulfur, while slower to act, is much easier to apply and less irritating.

Cost and convenience of applying are important items. Sometimes the cost of hauling will rule out a low-grade material. The methods of applying each material are given on pages 10 to 12.

TIME: how long will it take to get results and how much is it worth to you to get them soon?

Sulfuric acid is fastest—almost immediate. (See page 12.)
Gypsum takes a few weeks to a few months (page 10).

Sulfur takes a few months to a year, depending on soil conditions when it is applied (page 11).

HOW MUCH SHOULD YOU APPLY?

Usually sulfur materials are applied at a rate to furnish 1,000 to 1,500 pounds of sulfur per acre (see box, page 9). Amounts above 1 ton of sulfur per acre are not likely to pay you unless the cost is low or the value of the crop you plan to grow is great.

You might try an application at the rate of 1,000 pounds of sulfur per acre. After a trial crop, you can make an additional application on any spots where the crop has done poorly.

HOW DO SULFUR MATERIALS RECLAIM ALKALI SOILS?

What is needed to reclaim impermeable alkali soils is a supply of ***soluble calcium.***

Gypsum furnishes such a supply directly.

Most other sulfur materials do not contain soluble calcium, and furnish it only by reaction with lime (calcium carbonate). If your soil is one of the few that do not contain lime, you will need to add it when you use sulfur materials other than gypsum.

All of the sulfur materials, under the right conditions, result in the same essential change in the soil.

But there are differences in the way the various sulfur materials bring about soil changes, in the time they take to achieve results, and in the way they are applied. In order to choose the most economical sulfur material for your own situation, you need to understand these differences, as well as the essential change that is needed to reclaim your soil.

Soluble calcium is needed

You cannot leach the excess salts out of black alkali soil because it is impermeable to water. Sodium is what makes it impermeable.

The essential change needed to reclaim impermeable alkali soils is to replace sodium with *calcium*. What all of the sulfur materials do, directly or indirectly, is to supply *soluble* calcium for this change. You can compare the value of the materials for alkali reclamation on the basis of the amount of sulfur they contain (see below) only because this is a measure of the amount of soluble calcium they will supply. (You cannot compare them on the basis of calcium content—some of them do not contain calcium themselves, but supply it indirectly.)

Plants also supply soluble calcium: carbon dioxide given off by plant roots combines with water and calcium carbonate to bring some calcium into solution as bicarbonate. This is why, if you can grow crops on an alkali soil, you may be able to reclaim it by cropping alone.

1,000 POUNDS OF SULFUR IS SUPPLIED BY:

5,500 to 6,000 pounds of high-grade (95 per cent) gypsum
3,300 pounds (about 220 gallons) of 66° Baumé (93.2 per cent) sulfuric acid
2,000 pounds of sulfur dioxide
8,500 to 9,000 pounds of iron sulfate (copperas)
6,000 to 7,000 pounds of aluminum sulfate
3,400 pounds (about 327 gallons) of 32° Baumé lime-sulfur solution.

Gypsum . . .

. . . is the sulfur material most often used in alkali reclamation. Chemically, it is calcium sulfate ($CaSO_4 \cdot 2H_2O$), which is fairly soluble in water. Hence gypsum furnishes directly a supply of soluble calcium to replace and dilute sodium.

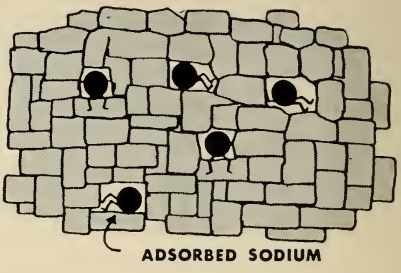
You can buy gypsum in mine-run grades which may contain as low as 15 per cent calcium sulfate; or as selected grades, which are 95 per cent pure or more. Chemically pure calcium sulfate contains 23.2 per cent calcium and 18.6 per cent sulfur. To find out how much sulfur there is in the grade you are thinking of buying, multiply 18.6 per cent by the percentage of calcium sulfate in that grade, as indicated on the identification tag. For example, gypsum containing 80 per cent calcium sulfate would contain $\frac{80}{100} \times 18.6$, or about 14.9 per cent sulfur. Mine-run gypsum that contains less than 70 per cent calcium sulfate would probably cost too much to haul except for locations very near the deposit.

You can broadcast gypsum on the soil. In order to do its job, gypsum must be dissolved in the soil solution. Hence you should work it lightly into the upper layers of soil so it will not be washed off, and then flood-irrigate. If you work it in too deeply, you will carry too much of the gypsum below the surface layers of soil, where it is most needed to condition the soil for seedlings.

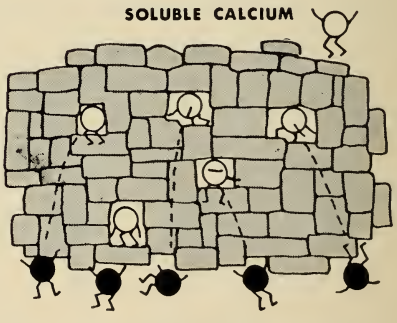
Or you can apply gypsum in irrigation water, either for treating the soil or for treating irrigation water itself. For such applications, it is important to use high-grade, finely powdered gypsum. Machines for adding powdered gypsum to irrigation water have been built by farmers and in machine shops. You can obtain information about them and about the technique of application from the Division of Irrigation, University of California, Davis, California.

HOW SOLUBLE CALCIUM RECLAIMS BLACK-ALKALI SOILS

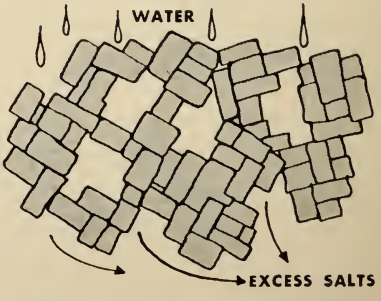
1 Too much sodium attached to clay particles tends to make the particles pack together in such a way that water cannot get through.



2 Sulfur materials furnish soluble calcium, which replaces the excess adsorbed sodium.



3 This replacement allows the soil particles to group themselves so that larger pore spaces are formed.



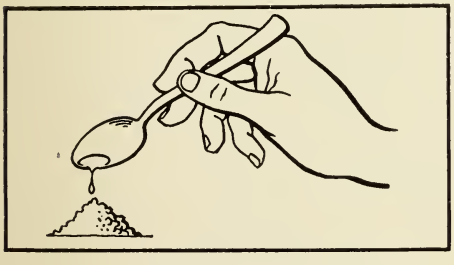
Then when the soil is flooded, the water can pass through and wash out excess salts, including sodium.

All other sulfur materials . . .

. . . (except lime-sulfur) supply calcium indirectly, and only through reaction with lime. Lime (calcium carbonate, $CaCO_3$) contains calcium, but in an insoluble form. Sulfur materials react with it to convert the calcium to a soluble form.

Most alkali soils contain enough lime to react with sulfur materials, but a few do not. If you are not sure whether your soil contains lime, you can make the simple test for it shown in the sketch below.

If there is no lime in your soil, you must apply it if you use any sulfur material other than gypsum or lime-sulfur. It is broadcast at the rate of about 2 tons per acre, and can be applied along with your sulfur material if you are broadcasting that. Applying lime is of course an additional expense; you will usually find it cheaper to use gypsum on a soil that lacks lime unless you get a very good buy on some other sulfur material and on lime. (You can still use gypsum if your soil contains lime; the additional calcium does no harm.)



TEST FOR LIME

Pour a teaspoon of strong acid, such as hydrochloric or sulfuric (maybe you can steal a little from your car battery) on a cup or less of soil. If the soil effervesces—if bubbling occurs—you can be sure that your soil has enough lime to react with sulfur materials. If it doesn't, you may have to have your soil tested: a few soils that contain lime will not respond to this test.

Sulfur . . .

. . . is widely used in alkali reclamation. Elemental sulfur (S) is not a direct source of calcium. It must first be oxidized to sulfuric acid, which must then react with lime to produce soluble calcium.

Sulfur is oxidized to sulfuric acid by the action of certain soil bacteria. This is a rather slow process that takes place only in warm, well-aerated, moist soil. If you apply sulfur in late fall or winter, it may have little or no effect until the following summer. But in the field, bacteria can oxidize sulfur in 6 weeks' time if you apply it in warm summer months, disk it in lightly, and then irrigate it.

If lime is available, the sulfuric acid first reacts with it to produce gypsum (calcium sulfate), carbonic acid (H_2CO_3) and calcium bicarbonate, $Ca(HCO_3)_2$. The gypsum and the calcium bicarbonate are sources of soluble calcium. Some of the carbonic acid breaks down into water and carbon dioxide, which escapes as a gas; but part of it acts further on the lime and produces calcium bicarbonate.

If all of the carbonic acid could be used to dissolve lime, elemental sulfur would be twice as effective as an equivalent amount of sulfur as gypsum. In reality, much less lime is dissolved in this way so that pure sulfur may be only a little more effective than an equivalent amount of gypsum.

Powdered sulfur is produced commercially at levels of purity ranging from 50 per cent to more than 99 per cent. What it is worth to you for reclamation depends upon how pure it is.

You can broadcast sulfur in the same way as gypsum. Because it is not soluble, you cannot apply it in irrigation water.

Sulfuric acid . . .

. . . is applied to the soil directly or in irrigation water. In either case it reacts with lime in the same way as when it is formed from elemental sulfur. With it,

however, you do not have to wait for the oxidation of the sulfur, and hence the reaction of sulfuric acid to form gypsum is very rapid. In fact, for reasons not yet understood, it seems to improve the soil even more rapidly than equivalent gypsum applications, in spite of having to go through an additional reaction to form gypsum. Results are almost immediate.

Commercial sulfuric acid is about 93 per cent pure. Pure sulfuric acid (H_2SO_4) contains about 32 per cent sulfur.

Sulfuric acid is difficult and dangerous to handle, and its application requires special equipment. You should not try to apply it yourself without a thorough understanding of the methods. Farmers usually contract for sulfuric acid applications with special operators who are equipped for and experienced in handling this chemical.

Do not allow sulfuric acid *when diluted* in irrigation water to run through concrete pipes or steel culverts or check gates because it will corrode them. (Strangely enough, *concentrated* sulfuric acid is less active on metal, and can even be shipped in steel drums and tank cars.)

Lime sulfur . . .

. . . is a clear, brown, highly alkaline liquid which contains calcium polysulfide and thiosulfate. It is the same solution that is used for spraying fruit trees to control insect pests and fungus diseases.

There is only a little calcium in lime-sulfur. The action of this material depends mostly on its sulfur content. Lime-sulfur, like elemental sulfur, must first be oxidized to sulfuric acid and then must react with lime to produce a soluble form of calcium.

You can use a lower grade of lime-sulfur for soil conditioning than is safe for spraying, but it should of course be correspondingly cheaper. Lime-sulfur for spraying is usually 32° Baumé and contains about 24 per cent chemically combined sulfur and about 9 per cent chemically combined calcium. Some lime-sulfur sold for soil conditioning has 23 per cent sulfur and 6 per cent calcium.

The solution is not corrosive to steel or cement. It is usually applied in the irrigation water.

Iron sulfate and aluminum sulfate . . .

. . . are known commercially as copperas and as cake or patent alum, respectively. Both materials can be obtained at high levels of purity and are very soluble in water. In the pure state, iron sulfate, $FeSO_4 \cdot 7H_2O$, contains about 12 per cent sulfur; and aluminum sulfate, $Al_2(SO_4)_3 \cdot 18\ H_2O$, contains about 15 per cent.

Both sulfates decompose in the soil to form—eventually at least—sulfuric acid and hydroxides of iron and aluminum. They act as soon as dissolved.

You can broadcast these materials in the same way as gypsum.

Sulfur dioxide . . .

. . . is a colorless, noninflammable gas (SO_2) with a strong, suffocating odor. It contains 50 per cent sulfur. When you add it to water it forms sulfurous acid, which is rapidly converted to sulfuric acid in the soil.

The pure gas is compressed to a liquid at very low pressures, and you can buy it in cylinders.

Sulfur dioxide is applied by dissolving it in the irrigation water. It has a limited solubility in water, so that the amount needed to condition the soil may have to be divided into two or three applications.

The acid is never strong enough under field conditions to be as corrosive as sulfuric acid. It also has usually been applied by contract operators.

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